Progress of ELSA in terms of Schedule and Work Packages

(Adapted from P2 activity report)

With a few exceptions (see problem areas reported in the management part) the recruitment of fellows has progressed well and according to plans, albeit with a delay of the order of 6 months - already reported in P1 - due to the complexity of the process. The first two annual network-wide meetings (after the kick-off) were held during P2, exactly according to the original plan, and were generally very successful (see evaluations). Networking activities in the form of short visits and secondments and the initiation of collaborative projects have begun.

In relation to the Work Packages (WP) and Tasks defined in the Description of Work (Annex I to the contract), the main achievements described below are reported. Note that these activities should be compared with the revised schedule of the tasks submitted with the P1 activity report (attached: ELSA_table1_rev1.pdf).

WP1 Space Astrometry

- **Task 11** (Research global methods of space astrometry in the framework of General Relativity): this task synthesizes the results of other tasks, concerning the sources of systematic and random errors, into the global solution (AGIS = Astrometric Global Iterative Solution). For this purpose a tool called AGISLab has been developed with main contributions from Lund, Heidelberg and ESAC. It consists of a set of java packages made available DPAC-wide (since Sep 2008) as part of the CU3 software repository. Generic interfaces allow AGISLab to implement a wide range of possible astrophysical, observational and instrumental effects in order to study their impact on the final astrometric errors.
- **Task 12** (Characterize sources of systematic errors in Gaia and research efficient methods for analyzing their effects on the final results): using AGISLab and other tools, we have started to study the effects of the surface structures of giant stars, weak microlensing by halo stars, systematic basic-angle variations, modifications to the nominal scanning law, and the distribution of dead time. The partners in Lund, Brussels, Cambridge, Heidelberg and INAF/Torino have so far been involved in this work, together with the DPAC groups at ESA and Dresden.
- **Task 13** (Quantify the accuracy of instrument calibrations and their impact on the final results): this task has not yet started since it depends largely on the results of WP2, which are not sufficiently advanced for incorporation in AGISLab.
- **Task 14** (Research the interdependence of astrometric, photometric and radial velocity information for space astrometry missions, including requirements for and availability of ground-based standards for external calibration purposes): contributions to this task concern the spatial distribution of stellar populations in external galaxies (Athens) to be introduced in the 'Gaia Universe Model' as part of CU2 simulation activities; detection of periodic variables with small amplitudes (Geneva) as part of CU7 variability processing activities, and stellar classification and determination of astrophysical parameters as part of CU8 activities (Ljubljana, Nice and INAF/Padova).

A major milestone achieved in Oct 2008 was that large-scale simulations of the astrometric solution could now be performed using AGISLab. This package is now used by several groups within ELSA (Brussels, Geneva, Heidelberg, Lund, Torino) as a tool for simulation, accuracy analysis and algorithm development. As an example, sky charts showing the nominal expected parallax accuracy after 1, 1.5 and 5 years of the mission are attached (skymaps.pdf).

WP2 Instrument Modelling

This WP focuses on the understanding and modelling of Charge Transfer Inefficiency (CTI) cause by radiation damage to the Gaia CCDs. We use theoretical models, Monte Carlo simulations, and analysis of laboratory test results made available by EADS Astrium in Toulouse in collaboration with the Gaia project team at ESA.

- **Task 21** (Study chromaticity and elaborate a calibration model): in the context of ELSA, no progress is reported on this task, because our attention has been focused on the more urgent and difficult CTI problem. The chromaticity (colour dependence of the PSF = Point Spread Function) is handled as part of the PSF modelling under DPAC/CU2, CU3 and CU5 activities (involving INAF/Torino, Leiden, Cambridge partners) and a generic calibration model is being implemented under the DPAC/CU3 activity (involving ESAC, Heidelberg and Lund). Its effect on the global accuracy will be studied in the next year using AGISLab.
- **Task 22** (Theoretical and empirical study of CTI effects): a heuristic model has been formulated (Leiden) and implemented as part of the Gaia image simulator (Paris). Monte Carlo simulation of the effects based on detailed physical modelling is the main PhD project of the ESR at Leiden. Astrium test results are being analysed (Cambridge, INAF/Torino). A workshop on CCD modelling will be held at Dutch Space on 19-20 Jan 2008.
- **Task 23** (Research and elaborate CTI calibration models for astrometry, photometry and radial velocity): analytical models aiming to represent the detailed Monte Carlo results and test data have been constructed (Lund, ESTEC) and are subsequently being compared with the results from Task 22 (Leiden, Cambridge).
- **Task 24** (Synthesis of study results from Task 21–23 in terms of PSF modelling for astrometry, photometry and radial velocities): on-going work as part of CU2 simulation activities (Paris, Barcelona) and CU3/CU5 Initial Data Treatment activities (Lund, Cambridge).

Milestone achieved: the CEMGA software package (CTI Effects Models for Gaia) available in DPAC software repository. It allows detailed prediction of effects using current knowledge of trap properties (attached example shows a simulation producing realistic amounts of charge loss and centroid shift: cti_simulation.pdf).

WP3 Numerical Analysis

- **Task 31** (Research and implement methods for scaled-down model solutions): this has been implemented in the framework of the AGISLab package, see Task 11 (Lund, Heidelberg).
- **Task 32** (Analyze methods for detection and management of outliers): simulation, detection and handling of Gaia attitude rate discontinuities due to micrometeoroid hits have been implemented as part of DPAC/CU3 astrometric processing activities (Lund) and knowledge transferred to DPAC/CU2 simulations (Barcelona, Leiden, Cambridge). More general outlier management schemes remain to be formulated and tested. AGISLab will be a main tool for this.
- **Task 33** (Study the impact of weighting schemes on accuracy and convergence): work on this task has not yet started. Again, AGISLab will be a main tool for this task.
- **Task 34** (Study alternative solution methods): the Gaia Sphere Reconstruction package is being developed at INAF/Torino as part of the DPAC/CU3 astrometric validation activities. The (non-)feasibility of a direct astrometric solution has been investigated (Heidelberg, Lund) resulting in a draft paper for A&A. The use of conjugate gradient methods for improved efficiency of the iterative astrometric solution has been studied (Heidelberg, Lund) and more recently (Dec 2008) successfully implemented in AGISLab.

Milestones achieved: test bed for numerical experiments implemented (as part of AGISLab); feasibility and efficiency of conjugate gradient algorithms for the astrometric solution demonstrated.

WP4 Data Processing

- **Task 41** (Study, implementation and optimisation of parallel supercomputing and GRID technology for Gaia data processing, with applications in the Gaia simulator, initial data treatment, object processing, and variability processing): parallel and distributed computing were important themes at the two network meetings held during the period (in Leiden, Nov 2007 and Barcelona, Sep 2008) as well as in the Java course (Jun 2008) attended by 7 of the ELSA fellows. Multithreaded Java code is now used in many of the data processing and simulation tasks developed within the network.
- **Task 42** (Detailed simulation of the instrument including knowledge from Tasks 21-23 to extensively test the PSF modelling in Task 24): this is developed as part of the DPAC/CU2 Gaia Instrument and Basic Image Simulator (Paris). The observation of dense regions in the Magellanic Clouds was studied in Athens using 2MASS data.
- **Task 43** (Detailed simulation of satellite dynamics for extensive testing the outlier management strategy in Task 32): development on the Gaia Attitude Model has recently started (Leiden, Cambridge) following the (delayed) appointment of the ER in Leiden.
- **Task 44** (Research optimal data processing methods for space astrometry of complex sources, with application to multiple stars and solar-system objects): the

astrometric effects of stellar brightness asymmetries (important for giants and supergiants) is studied in Brussels, partly in collaboration with Lund.

- **Task 45** (Research optimum data processing methods for irregular time series observations, with application to variable stars, eclipsing binaries and solar-system objects): methods to detect stellar variability from irregular time series are studied in Geneva. Orbit inversion methods for asteroids detected by Gaia are studied in Helsinki.

Milestones achieved: successful detection of small-amplitude periodic variables (>80% period recovery rate) at signal-to-noise ratio as low as 1.5 (Geneva); novel variants of asteroid orbit computation, using Markov-Chain Monte-Carlo methods, have been developed and tested (Helsinki).